Speed Adjustments Using Volume-Delay Functions

Volume-delay functions (VDFs) describe the speed-flow relationships in a travel demand model network based on the available link capacity. As traffic increases on the network, the resulting travel time and delay increase. In an effort to better represent delay due to congestion, some study areas estimate alternative volume-delay functions or construct speed-flow relationships based on observed data to achieve reasonable congested weighted speeds from the trip assignment model.

The following is a synopsis of the contributions made on the topic of adjusting travel model speeds (and resulting delay) using the volume delay function. Beyond the basic issues of which coefficients or alternative function(s) to apply, questions also arose regarding the degree at which speeds are controlled by the various functions.

Approaches

Based on contributions to the e-mail list, one of three approaches is typically applied with respect to VDF curves:

- Apply a single volume-delay formulation for all facility types,
- Apply unique user specified VDF functions developed for each facility type (e.g. freeway, expressway, arterials) and possibly area type in the network, and
- Develop unique user specified VDF functions to account for delay at signalized intersections.

The first approach applies a single volume-delay function for all facility types regardless of operating characteristics. In this instance, the Bureau of Public Roads (BPR) may be the most often applied speed-flow formula. The standard BPR coefficient values for alpha and beta are 0.15 and 4.00 respectively. Some study areas apply an alternative value for alpha and/or beta but these values remain constant across all facility types.

The derivation of alternate BPR functions using the second approach is typically based on comprehensive speed and travel time studies. As noted in an earlier technical synthesis on speed initialization practices, relatively few study areas have the resources to continually update and collect travel time and speed data. For those study areas that do collect speed and travel time data, the data could be used to "calibrate" network speeds and travel times with respect to observed volumes along the curve of the user specified VDF functions. Some contributors felt that any match between VDF-generated travel times and field-measured times in the base year, "will only be by coincidence, and won't hold for the future or for analyzing alternatives".

Variations of the BPR VDF (i.e. modifying the alpha and beta coefficients), conical functions, and applying alternative formulae, such as Akçelik's formula, attempt to progressively decay speeds faster with increasing V/C ratios to achieve desired speed-flow relationships in the base year condition. A number of contributors felt that the standard BPR curve overestimates speeds for volume-to-capacity (V/C) ratios greater than or equal to 1.0. One specific alternative approach noted by a contributor is to develop VDFs that produce different curves for V/C conditions above 1.0 and for conditions below 1.0. By varying the slope of the BPR curve, several contributors felt that resulting forecast speeds would be more accurate when congestion levels invariably increase in the forecast scenario. One contributor noted having a unique set of volume-delay curves for each time period as well.

Based on contributions to the e-mail list, it appears that the use of alternative VDF coefficients and alternative functions are commonly utilized in larger metropolitan areas. Denver, Los Angeles County, Atlanta, and Portland all indicated applications of locally derived speed-flow curves. Conclusions could not be formulated regarding practices at small to medium sized urban areas.

With the third approach, it was noted that the slope of the curve can be modified to better reflect the different speed-flow characteristics between access controlled facilities, such as freeways, and facilities with signalized controlled intersections (e.g. arterials) by varying the alpha and beta parameters for each facility type. One contributor also indicated that in addition to user specified VDF functions for each facility type the data can be augmented with estimates of delay for facilities with signalized intersections if that data is available.

Minimum Allowable Speed Degradation

Because of the asymptotic nature of volume-delay curves, also described as "monotonically increasing functions" with respect to travel times, speed adjustment factors are allowed to continue infinitely until speeds reach, "unrealistically low," values. Based on contributions to the e-mail list, there are considerable variations in national practice with respect to defining a minimum speed with which to allow resulting travel speeds to degrade during the trip assignment process. Indeed, a debate exists among contributors as to whether implementing such a criteria is even justifiable.

The motivation for implementing minimum speed thresholds or "floors" (as they are sometimes referred to) is to match observed base year network speeds and/or observed travel times (if these are available). By doing so, some contributors felt that the traffic assignment results may be more practical for planning purposes and useful (e.g. "realistic" congested speeds needed for mobile source emission modeling). Several contributors recommended a range of 8 to 17 mph as the minimum allowable congested speed, while others noted the use of minimum speed ratios (i.e. the ratio of congested to free-flow speed for different facility types).

With respect to speed floors, concerns included:

- Model assignment process becomes less sensitive to volume changes (may be seen as a benefit in an equilibrium assignment process since it may converge more quickly).
- Model feedback process becomes less sensitive for links with unrealistically high congestion levels (e.g. links exceeding a V/C ratio of two).
- Model may produce results where higher V/C ratios yield higher speeds than links with lower V/C ratios. As one contributor questioned, "Doesn't it make sense within equilibrium assignment to have a lower speed for V/C = 2.63 than V/C = 1.2"?
- Model results may be rendered impractical for future year analysis between scenarios or competing alternatives.

Other's noted that unrealistically low speeds may be a result of faulty underlying assumptions, such as the capacity used and the peak-hour factors used to derive peak period or daily capacity. Extremely low resulting link speeds may also highlight problems in the time-of-day trip tables as one contributor noted.

Utilizing Processed Speeds

Alternative volume-delay functions are also utilized to post-process speeds for the purpose of mobile source emissions modeling. Since models are calibrated to match regional or cordon line traffic counts, the resulting speeds may be inconsistent with observed speeds at the corresponding V/C ratio. Therefore, the speeds that are produced by the travel models need to be post-processed and refined to produce more realistic network link specific values for use in mobile source emission modeling. The speeds (based on the resulting assigned V/C ratios) are processed using alternative volume-delay equations that are typically independent from the VDFs used in the travel model.

A question arose as to whether it was valid to use the post-processed speeds as part of the feed-back process to derive the final congested weighted speeds. According to contributions to the e-mail list, the accepted national practice is to apply the unadjusted or non-processed speeds back through trip distribution and mode choice. Thus, the base year model is, “calibrated with the link specific speeds and not a post-processed speed”. Speeds are only post-processed once the appropriate model assignment results have been achieved.

Conclusions
Based on contributions to the e-mail list, only a relatively few study areas have conducted current and comprehensive speed and travel time studies to support the development of locally derived volume-delay functions. Despite this, the application of user specified volume-delay function curves to control resulting assigned speeds (and therefore the congested impedance in an equilibrium assignment application) appears to be common practice among many large urban areas. With the exception of a very few large urban areas, models are typically not calibrated to match observed speeds.

Several contributors weighed in with sound reasoning and justification for modifying the volume-delay functions locally. Others expressed reservations as to the viability of such tight base year constraints with respect to speeds, delay and diversion. One contributor opined whether it is possible to produce a model that can calibrate to observed speed conditions (and observed flow conditions) and yet remain viable for forecast scenarios where those conditions will most likely be different. Interim year verification may offer a resolution to this question.

Furthermore, the travel demand modeling community does not appear to have reached a consensus as to whether VDF constructs such as preventing speeds from decaying to unrealistically low values during the trip assignment process should be implemented. Convincing arguments for and against VDF constructs were made by contributors to the discussion.